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SL1310V1-20024 - May 15, 2018

Item # SL1310V1-20024 was discontinued on May 15, 2018. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

MEMS-VCSEL SWEPT-SOURCE LASERS, 1300 NM

- ▶ **100 kHz and 200 kHz Options**
- ▶ **Over 100 mm Coherence Length**
- ▶ **Single Mode, Mode-Hop-Free Operation**
- ▶ **Linear Sweep Trajectory**

SL1310V1-20048

OVERVIEW

Features

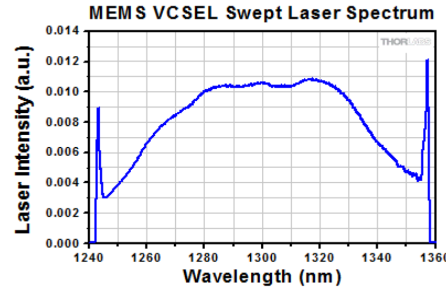
- Benchtop Swept-Source Lasers Ideal for Optical Coherence Tomography
- Includes Integrated Mach-Zehnder Interferometer (MZI) for Wavenumber Triggering
- Three Configurations Available:
  - 100 kHz with 48 mm MZI k-Clock Delay
  - 200 kHz with 48 mm MZI k-Clock Delay
  - 200 kHz with 24 mm MZI k-Clock Delay
- Custom Speeds and Configurations up to 200 kHz Available Upon Request

Common Specifications	
Center Wavelength	1300 nm
Duty Cycle (Unidirectional Sweep)	>65%
Wavelength Tuning Range (-20 dB)	>100 nm
Coherence Length	>100 mm
Average Output Power[a]	>20 mW
Relative Intensity Noise (RIN)	<1.0%
Ripple Noise Suppression	-47 dB

- Measured at laser output aperture. Valid over the entire wavelength range.

Thorlabs Benchtop MEMS-VCSEL Swept-Source Lasers are designed for high-speed, long-range, optical coherence tomography (OCT) applications. Developed in partnership with Praevium, a strategic partner of Thorlabs, these swept-source lasers are based on a patented Microelectromechanical System (MEMS) which tunes a Vertical Cavity Surface Emitting Laser (VCSEL). With a record-breaking coherence length, this source provides single mode, mode-hop-free operation over a tuning range in excess of 100 nm.

The benchtop swept-source lasers sold here incorporate all of the drive electronics,



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Click here to download the raw data.
The scanning trajectory of the MEMS mirror is optimized for linearity across the sweep. As a result, the MEMS mirror dwells at the edges of the sweep, thereby causing peaks in the emitted spectrum.

temperature controllers, and triggers necessary for easy integration into custom SS-OCT systems. For further details, please see the *Product Details* Tab.

Wavenumber Triggering Options
All Thorlabs' SL1310V1 swept-source lasers include an integrated Mach Zehnder interferometer for digital "k-clock" triggering. Due to limitations in detection and data acquisition electronics, the speed and coherence length capabilities of our MEMS-VCSEL technology cannot be fully harnessed at this time. For this reason, we offer three laser configurations that are optimized for maximum imaging range at the most common data acquisition rates. Custom speeds and configurations up to 200 kHz of the SL1310V1 Benchtop Laser Source are available. Please contact Thorlabs' Technical Support for more information.

The SL1310V1-10048 laser source provides a 12 mm imaging range at 100 kHz sweep speeds when using a 500 MS/s data acquisition card. Comparatively, the SL1310V1-20048, which operates at a 200 kHz sweep speed, requires a minimum of 1 GS/s data acquisition to achieve a 12 mm imaging range. For applications that require a high sweep speed but not an exceptionally long imaging range, or those that are limited in data acquisition speed, the SL1310V1-20024 laser source can provide a 6 mm imaging range at 200 kHz when using a 500 MS/s data acquisition card. For more details on these configurations, please see the *Specs* Tab.

SPECS

General Specifications

	Minimum	Typical	Maximum
Central Wavelength	1285 nm	1300 nm	1315 nm
Wavelength Tuning Range (-20 dB Cut Off Point)	100 nm	-	-
Coherence Length	100 mm	-	-
Storage/Operating Temperature	10 °C	25 °C	40 °C
Average Output Power[a]	20 mW	25 mW	50 mW
Duty Cycle (Unidirectional Sweep)	>65%		
Relative Intensity Noise (RIN)[b]	<1.0%		
Ripple Noise Suppression	-47 dB		
Humidity	>85%, Non-Condensing Environment		
Supply Voltage[c]	100 - 240 VAC, 50/60 Hz		
Laser Classification (per IEC 60825-1)	Class 1M		
Dimensions (L x W x H)	321 mm x 320 mm x 150 mm (12.4" x 11.6" x 5.75")		

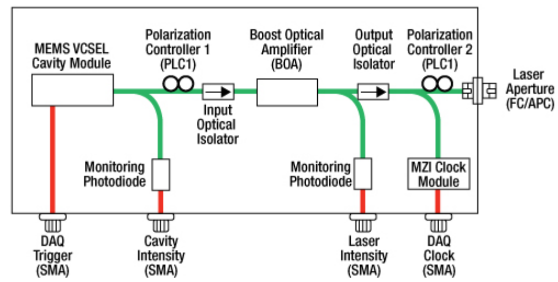
- Measured at laser output aperture. Valid over the entire wavelength range
- Measured using a detector with DC to 400 MHz bandwidth and averaged over all output wavelengths
- Swept source has universal AC input

Item #	SL1310V1-10048			SL1310V1-20024			SL1310V1-20048		
	Min	Typical	Max	Min	Typical	Max	Min	Typical	Max
Scan Repetition Rate	99 kHz	100 kHz	101 kHz	198 kHz	200 kHz	202 kHz	198 kHz	200 kHz	202 kHz
Integrated MZI Interferometer Delay	46 mm	48 mm	50 mm	23 mm	24 mm	25 mm	46 mm	48 mm	50 mm

Supported OCT Imaging Depth Range	11.5 mm[a]	12 mm[a]	12.5 mm[a]	5.5 mm[a]	6 mm[a]	6.5 mm[a]	11.5 mm[b]	12 mm[b]	12.5 mm[b]

- Measured when using 500 MS/s DAQ
- Measured when using 1 GS/s DAQ

PRODUCT DETAILS



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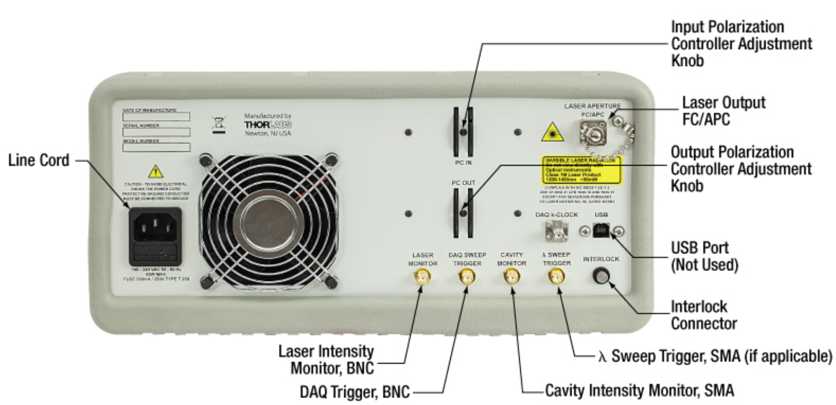
Thorlabs' MEMS-VCSEL benchtop lasers incorporate all the necessary drive electronics, temperature controllers, trigger signals, and optical isolators for easy operation and integration into any swept-source OCT system. Additionally, these benchtop laser sources utilize a specially designed Mach-Zehnder Interferometer "k-clock" that provides a digital output signal for triggering data acquisition.

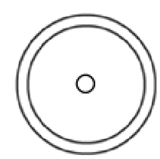
The figure to the right shows a schematic of the MEMS-VCSEL benchtop laser. These lasers consist of a MEMS-VCSEL cavity, a booster optical amplifier (BOA), a fiber-optic monitoring network, and signal generation circuits. The optical output of the MEMS-VCSEL cavity module is connected to the optical input of the BOA. A polarization controller (PLC1) is used to control the polarization states of the light in the fiber when entering the BOA. Another polarization controller (PLC2) is used to control the output fiber polarization before the main laser output.

The "DAQ Trigger" provides a line trigger whereas the "DAQ Clock" is a digital output from the MZI "k-clock" to trigger data acquisition that is linear in wavenumber. Laser monitoring ports are also provided from the output of the MEMS-VCSEL Cavity (Cavity Intensity) and after amplification (Laser Intensity). Integrated optical isolators in the benchtop laser sources eliminates the need for additional isolators external to the laser.

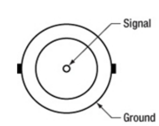
REAR PANEL



SMA Female



BNC Female



MEMS VCSEL TUTORIAL

VCSEL Overview

Vertical Cavity Surface Emitting Lasers (VCSELs) are semiconductor-based devices that emit light perpendicular to the chip surface, as shown in Figure 1. VCSELs were originally developed as low-cost, low-power alternatives to edge-emitting diodes, mainly for high-volume datacom applications. Quickly thereafter, the advantages of VCSELs became evident, leading to them being preferred light sources over edge-emitters in many applications. Compared to edge-emitting sources, VCSELs offer superior output beam quality and single mode operation.

MEMS-tunable VCSELs utilize microelectromechanical mirror systems (MEMS) to vary the cavity length of the laser, thereby tuning the output wavelength. MEMS-tunable VCSELs have existed for several years; however, the limited tuning range and output power of these devices have precluded them from being used in OCT applications. Praevium Research, in cooperation with Thorlabs and MIT, has since developed a MEMS-tunable VSCEL design that overcomes these previous limitations.

In order for a MEMS-tunable VCSEL to be successful for applications in OCT, it needs to meet certain standards:

- Rapid Sweep Speed
- Broad Tuning Range
- Long Coherence Length
- High Laser Output Power

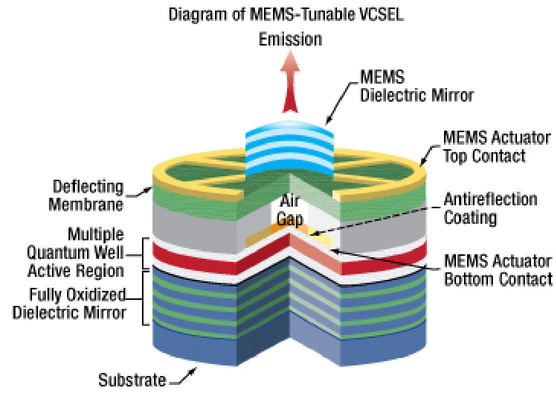


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Figure 1: Praevium's MEMS-Tunable VCSEL is an innovative design that offers high-speed and broadband emission with long coherence length. This is an ideal combination for an OCT swept laser source.

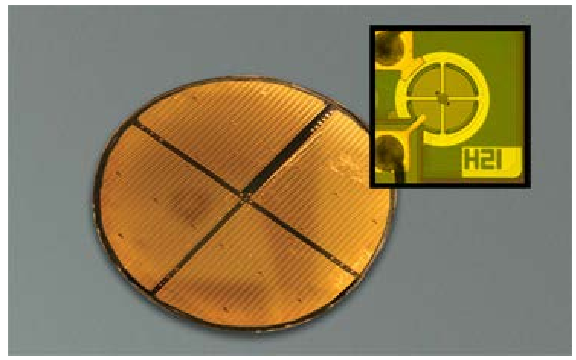

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Figure 2: MEMS-tunable VCSELs can be densely packed on a single wafer to increase the potential yield. The inset shows a single MEMS-tunable VCSEL device after fabrication. The overall size of the MEMS-tunable VCSEL is approximately 600 µm x 600 µm square.

Rapid Sweep Speed

Applications using OCT demand high-speed imaging without sacrificing imaging quality. Fast imaging rates allow better time resolution, dense collection of 3D datasets, and decreased laser exposure times to the sample.

Currently, there exist a few swept-source lasers that offer high-speed scanning. Fourier domain mode-locked lasers, for example, achieve extremely high imaging speeds but require the use of very long fiber optic delays in the laser cavity and can only operate in wavelength ranges where the fiber loss is low. Of the commercially available high-speed swept lasers, many operate with multiple longitudinal modes or have long cavity lengths, which limit coherence length or tuning speed, respectively.

The low mass of the MEMS-tuning mirror in a MEMS-based tunable VCSEL and the short cavity length both contribute to its high-speed operation. The short cavity length also places only one mode in the gain spectrum, enabling single-mode continuous operation. In addition, the short cavity design enables nearly identical spectral in the forward and backward sweeps. We have recently measured greater than 500 kHz sweep rates using a MEMS-tunable VCSEL prototype, without using optical multiplexing to increase the sweep speed.

Broad Tuning Range

High-resolution imaging depends on the overall tuning bandwidth of the swept-source laser. Praevium boasts the broadest bandwidth MEMS-tunable VCSEL that has ever been developed. A unique design incorporating broadband, fully oxidized mirrors, as well as wideband gain regions and thin active regions, has currently resulted in greater than 100 nm of continuous mode-hop-free tuning, centered around 1300 nm. For details, please see Figure 3.

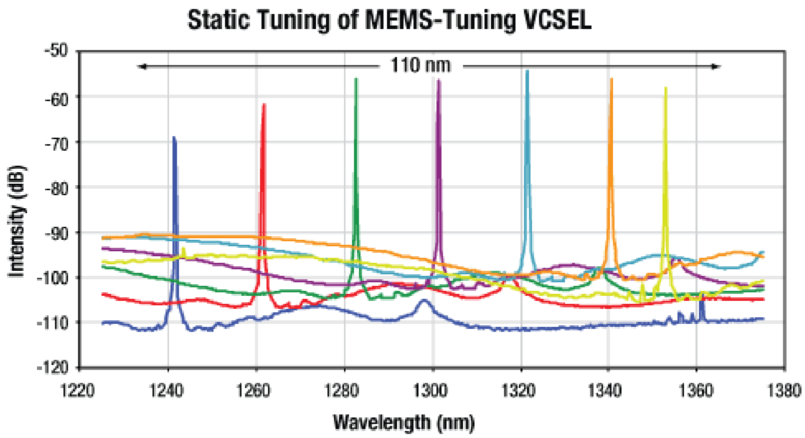

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Figure 3: MEMS-tunable VCSELs are capable of tuning over 100 nm. Here we show single-mode operation over a 110 nm spectral tuning range centered at 1300 nm.

Long Coherence Length

A significant limitation to most OCT systems is the depth of view (maximum imaging depth range). Especially in clinical applications, where sample thickness, patient motion, and sample location cannot be controlled, a long depth of view is advantageous. A long coherence length alone, however, is not enough. Image sensitivity needs to be virtually unaffected throughout the entire depth. Due to the micron-scale cavity length of the VCSEL and single mode, mode-hop-free operation, we have measured coherence lengths of greater than 50 mm from our MEMS-tunable VCSEL with nearly no signal degradation. Currently limited by detector bandwidth, we are confident that the MEMS-tunable VCSEL is able to achieve even longer imaging depths than have been measured to date. This remarkable depth of view will not only benefit the medical imaging community but also open doors to other applications such as large objective surface profiling, fast frequency domain reflectometry, and fast spectroscopic measurements with high spectral resolution.

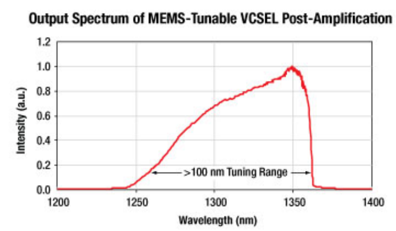

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Figure 4: Spectrum of MEMS-tunable VCSEL operating at 200 kHz, with a center wavelength around 1310 nm, and post amplification using an SOA. Continuous development of these sources has indicated the capability of tuning over 110 nm of bandwidth.

High Output Power

Increased imaging speed often comes at the cost of decreased output power and/or optical power on the sample. One advantage of edge-emitting light sources over VCSELs is that they can emit greater output powers. As a general rule, most OCT imaging applications need a minimum of 20 mW of laser output power to maintain image quality when operating at faster scan rates. To reach this goal, the MEMS-tunable VCSEL is coupled with a semiconductor optical amplifier (SOA) to achieve greater than 25 mW of power. An additional advantage of this post-amplification scheme is that the SOA reshapes the MEMS-VCSEL output spectrum such that it is much more uniform.

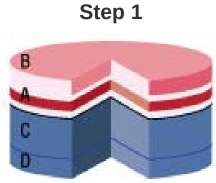
Additional Considerations and Manufacturing Capabilities

A special feature of the MEMS-tunable VCSEL is that it is scalable for different wavelengths. Through innovative combinations of gain materials and dielectric mirrors, a wide wavelength range in the visible or near infrared can be reached, enabling expansion of this new family of light sources.

As we further develop this light source, we look forward to finding new and exciting applications for its use. Please contact us to discuss how a MEMS-tunable VCSEL may advance your research.

Fabrication of a MEMS-Tunable VCSEL

Step 1



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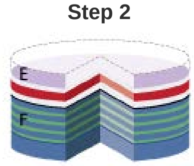
The VCSEL wafer begins with a multiple quantum well (MQW) active region (A) that is grown on an InP substrate (B) and bonded to a GaAs-based mirror (C) grown

Step 2



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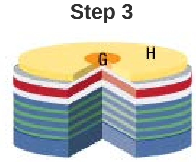
The InP substrate is chemically etched down to a strategically located stop-etch layer (E). The GaAs-based mirror is oxidized to create a wideband dielectric mirror (F).

Step 3



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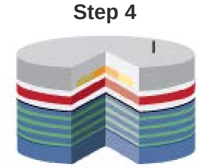
After removal of the stop-etch layer, an AR coating (G) and annular MEMS bottom actuator contact (H) are deposited on top of the MQW active region.

Step 4



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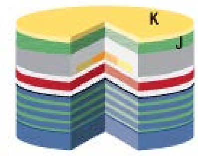
A sacrificial layer (I) of a specifically designed thickness and composition is deposited.

Step 5

on a GaAs substrate (D).



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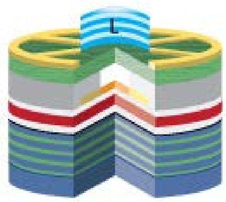
A membrane layer (J) and annular top MEMS actuator contact (K) are deposited on top of the sacrificial layer.

Step 6



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Finally, a dielectric mirror (L) is deposited and patterned. The top MEMS contact is further patterned to complete creation of the actuator. The sacrificial layer is undercut to leave a suspended, moveable top mirror above the MQW structure, producing a VCSEL with a MEMS-based tuning element in a single device.

LASER SAFETY

Laser Safety and Classification

Safe practices and proper usage of safety equipment should be taken into consideration when operating lasers. The eye is susceptible to injury, even from very low levels of laser light. Thorlabs offers a range of laser safety accessories that can be used to reduce the risk of accidents or injuries. Laser emission in the visible and near infrared spectral ranges has the greatest potential for retinal injury, as the cornea and lens are transparent to those wavelengths, and the lens can focus the laser energy onto the retina.

Safe Practices and Light Safety Accessories

- Thorlabs recommends the use of safety eyewear whenever working with laser beams with non-negligible powers (i.e., > Class 1) since metallic tools such as screwdrivers can accidentally redirect a beam.
- Laser goggles designed for specific wavelengths should be clearly available near laser setups to protect the wearer from unintentional laser reflections.
- Goggles are marked with the wavelength range over which protection is afforded and the minimum optical density within that range.
- Blackout Materials can prevent direct or reflected light from leaving the experimental setup area.
- Thorlabs' Enclosure Systems can be used to

contain optical setups to isolate or minimize laser hazards.
- A fiber-pigtailed laser should always be turned off before connecting it to or disconnecting it from another fiber, especially when the laser is at power levels above 10 mW.
- All beams should be terminated at the edge of the table, and laboratory doors should be closed whenever a laser is in use.
- Do not place laser beams at eye level.
- Carry out experiments on an optical table such that all laser beams travel horizontally.
- Remove unnecessary reflective items such as reflective jewelry (e.g., rings, watches, etc.) while working near the beam path.
- Be aware that lenses and other optical devices may reflect a portion of the incident beam from the front or rear surface.
- Operate a laser at the minimum power necessary for any operation.
- If possible, reduce the output power of a laser during alignment procedures.
- Use beam shutters and filters to reduce the beam power.
- Post appropriate warning signs or labels near laser setups or rooms.
- Use a laser sign with a lightbox if operating Class 3R or 4 lasers (i.e., lasers requiring the use of a safety interlock).
- Do not use Laser Viewing Cards in place of a proper Beam Trap.

Laser Classification

Lasers are categorized into different classes according to their ability to cause eye and other damage. The International Electrotechnical Commission (IEC) is a global organization that prepares and publishes international standards for all electrical, electronic, and related technologies. The IEC document 60825-1 outlines the safety of laser products. A description of each class of laser is given below:

Class	Description	Warning Label
1	This class of laser is safe under all conditions of normal use, including use with optical instruments for intrabeam viewing. Lasers in this class do not emit radiation at levels that may cause injury during normal operation, and therefore the maximum permissible exposure (MPE) cannot be exceeded. Class 1 lasers can also include enclosed, high-power lasers where exposure to the radiation is not possible without opening or shutting down the laser.	
1M	Class 1M lasers are safe except when used in conjunction with optical components such as telescopes and microscopes. Lasers belonging to this class emit large-diameter or divergent beams, and the MPE cannot normally be exceeded unless focusing or imaging optics are used to narrow the beam. However, if the beam is refocused, the hazard may be increased and the class may be changed accordingly.	
2	Class 2 lasers, which are limited to 1 mW of visible continuous-wave radiation, are safe because the blink reflex will limit the exposure in the eye to 0.25 seconds. This category only applies to visible radiation (400 - 700 nm).	
2M	Because of the blink reflex, this class of laser is classified as safe as long as the beam is not viewed through optical instruments. This laser class also applies to larger-diameter or diverging laser beams.	
3R	Lasers in this class are considered safe as long as they are handled with restricted beam viewing. The MPE can be exceeded with this class of laser, however, this presents a low risk level to injury. Visible, continuous-wave lasers are limited to 5 mW of output power in this class.	
3B	Class 3B lasers are hazardous to the eye if exposed directly. However, diffuse reflections are not harmful. Safe handling of devices in this class includes wearing protective eyewear where direct viewing of the laser beam may occur. In addition, laser safety signs lightboxes should be used with lasers that require a safety interlock so that the laser cannot be used without the safety light turning on. Class-3B lasers must be equipped with a key switch and a safety interlock.	
4	This class of laser may cause damage to the skin, and also to the eye, even from the viewing of diffuse reflections. These hazards may also apply to indirect or non-specular reflections of the beam, even from apparently matte surfaces. Great care must be taken when handling these lasers. They also represent a fire risk, because they may ignite combustible material. Class 4 lasers must be equipped with a key switch and a safety interlock.	
All class 2 lasers (and higher) must display, in addition to the corresponding sign above, this triangular warning sign		

Part Number	Description	Price	Availability
SL1310V1-10048	100 kHz MEMS-VCSEL Swept-Source Laser, 48 mm MZI k-Clock Delay	$35,000.00	Lead Time
SL1310V1-20048	200 kHz MEMS-VCSEL Swept-Source Laser, 48 mm MZI k-Clock Delay	$35,000.00	Lead Time
SL1310V1-20024	200 kHz MEMS-VCSEL Swept-Source Laser, 24 mm MZI k-Clock Delay	$35,800.00	Lead Time